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RESEARCH IN SUPPORT OF JCINT ARMY-NAVY AIR CREW IMPACT INJURY P--ETC(U)

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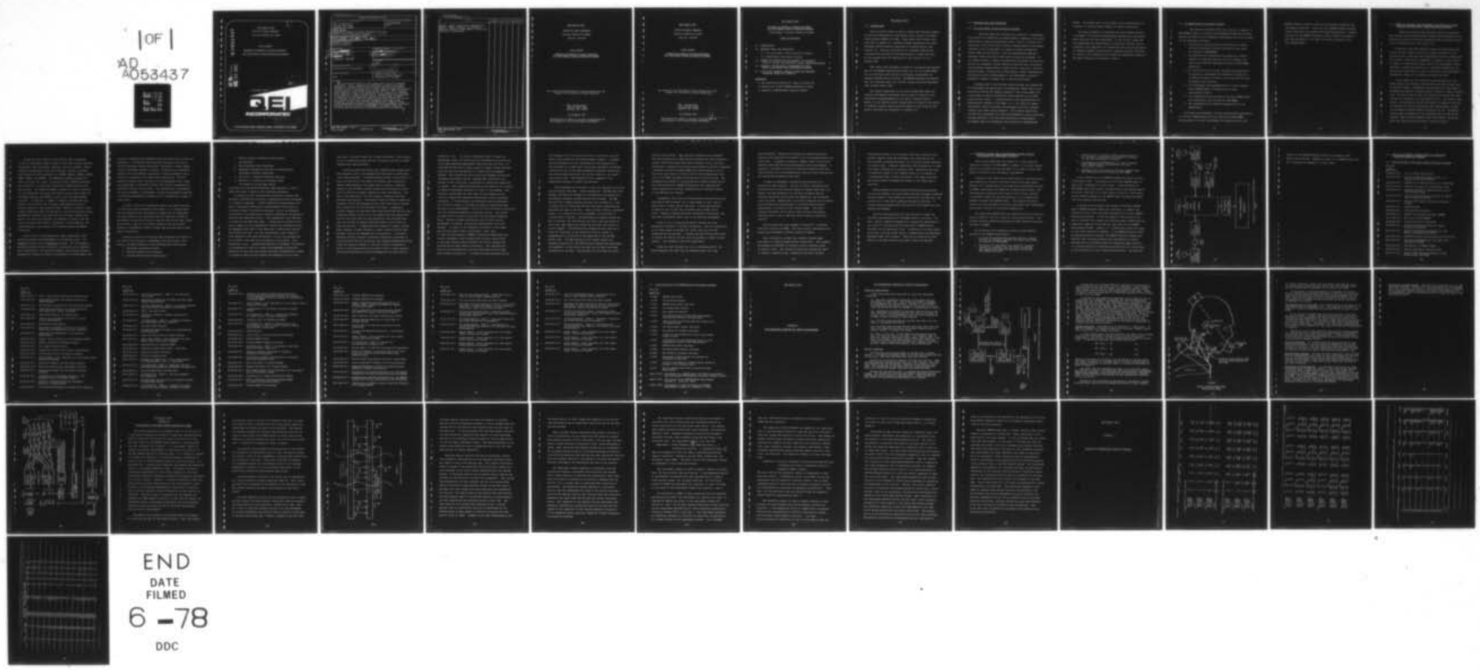

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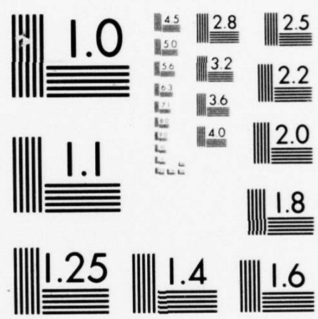

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QEI Report 7C31

OFFICE OF NAVAL RESEARCH

Contract N00014-70-C-0082

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FINAL REPORT

Research in Support of Joint Army-Navy Air Crew Impact Injury Prevention Program

31 December 1977

QEI INCORPORATED

119 The Great Road, Bedford, Mass. 01730 (617) 275-6800

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13. ABSTRACT

The research described in this paper falls into two separate categories. First, research was performed to develop and apply mathematical models which would accurately simulate the dynamic response of the living human over a wide range of impact-accelerative forces applied to the human along various vectors. This research would hopefully lead to the specification of a manikin to simulate human response to impact acceleration. Research was also performed to determine the physiological response of the human to impact acceleration or the effect of impact-accelerative forces on cardiac and pulmonary functions, skeletal integrity and organ tissue integrity. Second, research was performed and a computer model called MEDCON was developed to determine the requirements in medical personnel and facilities of NAVY-BUMED at different times and locations before and during a precisely-specified contingency.

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Research in Support of Joint Army-Navy Air Crew Impact Injury Prevention Program

Final Report Contract N00014-70-C-0082

Table of Contents

1.0 INTRODUCTION

This is the final report of QEI's research and technical support of the Joint Army-Navy Air Crew Impact Injury Prevention Program under Contract N00014-70-C-0082. Tasks under this contract were performed in support of a research program sponsored by the Naval Aerospace Medical Research Laboratory at Michoud Station, New Orleans, LA. Work was initiated as of 1 November 1969 and has continued with the addition and modification of tasks and scope of the program until the completion of the contract as of 31 October 1977.

This report also includes an account of the design and development of the MEDCON computer-based model for the use of NAVY-BUMED for the planning of Navy medical contingency requirements for medical personnel and facilities. The MEDCON research and development was conducted under this contract during the period September 1974 through January 1976.

This report summarizes all the work accomplished under the contract and supplies references and an index to reports of all significant accomplishments for the entire research project. Details of the research effort accomplished are found in the series of technical reports which have been issued in the course of this project and which are referenced in Chapter 5.0.

2.0 RESEARCH GOALS AND OBJECTIVES

2.1 Air Crew Impact Injury Prevention Program

The work under this contract was initiated to investigate the inertial (or kinematic) and physiological response of the living human being to impact-acceleration forces. The U.S. military services have a need for the best possible understanding of the dynamic response of the living human to a range of impact-accelerative forces along various vectors. Such an understanding underlies important issues relating to many injury prevention programs. It is closely related to issues concerned with the design of protective devices for emergency aircraft egress by ejection seat, protection from parachute opening shock at high aircraft velocities, restraint harness design, aircraft pilot helmet design, cockpit configuration optimization and an understanding of the mechanisms of injuries produced to vehicle occupants due to impact-acceleration.

A primary goal of the research conducted under the program was the development and application of mathematical models which would accurately simulate the dynamic response of the living human over a wide range of impact-accelerative forces applied to the human along various vectors. A second objective was concerned with the physiological response of the human, i.e., the effect of impact-accelerative forces on cardiac and pulmonary functions, skeletal integrity and organ tissue integrity. The research objectives included the requirement for precise measurements in data collection, thorough analysis of the data and correlation of experimental bio-dynamic data for formulation and validation of mathematical

models. An ultimate goal of this effort is the specification of a manikin to simulate human response to impact acceleration.

The above statement of objectives for this program reflects a refinement of focus and understanding achieved over the several years this work has been undertaken. In the initial stages the work emphasized the identification of essential factors, the determination and compilation of significant data and the generation of computer programs and routines to organize the data collected, all aimed at the formulation and testing of mathematical models of the human response to accelerative forces.

2.2 The MEDCON Model Development Program

The research conducted under this contract in support of NAVY-BUMED studies on planning and programming guidelines for Navy medical and health care contingency requirements was first focussed on the following task areas:

1. The review of existing and available doctrine, models and data pertaining to medical and health care needs of interest to NAVY-BUMED.
2. The derivation of requirement and capability formulas capable of producing time care units for medical and health care needs and applicable within the NAVY-BUMED guidelines.
3. The identification of factor variances and modifiers to be applied to requirement and capability formulas for the NAVY contingency situation in war time and the time preceding a war situation.
4. The development and implementation of a basic computer model (MEDCON model) incorporating the basic requirements formula.
5. The substantiation and testing of the basic MEDCON model with appropriate data provided by NAVY-BUMED.
6. The implementation of enhanced capabilities for the MEDCON model.

Following the development, testing and successful application of the basic MEDCON model with data supplied by NAVY-BUMED, QEI responded to further requirements for capabilities for the

MEDCON program to handle a spectrum of different parameters and contingency situations. Since the first MEDCON program required inputs which had to be compiled and presented manually, a further extension of the MEDCON development effort aimed at the improvement and automation of the input and output processes of the basic MEDCON model.

3.0 SUMMARY OF RESEARCH AND DEVELOPMENT AND TECHNICAL SUPPORT FOR THE AIR CREW IMPACT INJURY PREVENTION PROGRAM

Under this contract QEI performed research and development studies and provided technical support and assistance for the director and staff of the Naval Aerospace Medical Research Laboratory at Michoud Station, New Orleans, LA.

In general terms this program of human bio-engineering comprised two major areas of effort: (1) research studies of time varying forces, velocities and displacements which are experienced by a subject human being, chimpanzee or cadaver, as they relate to impact or accelerative forces; and (2) the development, implementation, testing and application of computer programs for the analysis and organization of data to facilitate the development of mathematical models of the dynamic processes involved.

In the conduct of this work which was carried out at the NAMRL Laboratory at Michoud Station sled runs with various types of subjects (humans, chimpanzees and cadavers) have been made to determine the physical and physiological effects of impact acceleration. Two basic types of data are obtained from these sled runs: inertial (or kinematic) and physiological data. The inertial data consist of analog data derived from sensors attached to the subject during the sled run and optical data (photographs, x-rays) of the subjects obtained before and during the run. The physiological data is divided into the following types of data on the subjects: EKG and blood chemistry data taken before, during and after the sled runs and the subject's medical history.

During the early stages of the contract, QEI contributed to the two dimensional impact studies in the areas of data analysis, programming, data processing, modeling, and error studies. Major computer programs which have been developed, refined, verified and documented by QEI personnel are: CHNGVR, DSCALE, ICONDS, OUTVAR, TROUT, TROUTP, and NCKSTR. The CHNGVR and DSCALE programs are used to process the sensor acceleration data, CHNGVR performing the conversion to a new output format while DSCALE performs the data scaling. The OUTVAR and TROUT programs are used to construct the two dimensional data base from sensor variable data output by the DSCALE program, and TROUTP is used to plot the photographic variables. In addition, a number of computer analyses were performed, concerned with the 2-D impact experiments, relating to Fourier analysis of the transducer data, center of rotation, accelerometer phase-log error and testing of a new A/D conversion system. Mathematical analyses concerned with the 2-D impact studies were made in the areas of kinematics, accelerometer location, A/D conversion, analog versus digital computation, linear modeling, nonlinear modeling, error studies and collocation and misalignment corrections.

In the areas of three-dimensional impact experiments, QEI performed analyses and programming in two separate areas: 3-D <u>kinematic</u> analyses and 3-D <u>geometric</u> analyses. The 3-D kinematic analyses performed by QEI consisted in discussion of the possible use of quaternions, 3-D simulation studies, and studies including mathematical analyses of special accelerometer or accelerometer and

rate-gyro configurations designed for optimal measuring of motions in 3 dimensions. 3-D analyses were also made relating to the use of various coordinate system conventions, conversion of Euler angles from one coordinate system to another, conversion of acceleration signals from accelerometer coordinates to head coordinates and to laboratory coordinates and simple test trajectories. The 3-D geometric analyses were required for the processing of the x-rays and photographs to establish internal and external anthropometric coordinate systems and locations. The analyses have investigated the type and number of photographs, targets and parameters required to establish photographic calibration of a 3-dimensional volume of object space.

Studies on the use of regression analysis on impact acceleration data were also performed in an attempt: (1) to provide guidance in planning future experiments on humans and on chimpanzees and human cadavers (by identifying the more important variables determining the particular form of head and neck motion under impact acceleration); and (2) to provide information for the further design of a mathematical model of human head and neck motion under impact acceleration.

During the course of this project QEI personnel contributed in the areas of data analysis, programming, data processing, error studies, and model analysis to the following major task groups:

1. Horizontal Accelerator Studies
2. EKG Data Analysis and Processing
3. Sled Run Motion Picture Digitization

4. Medical History Information System Design and Operation
5. Blood Chemistry Data Processing
6. Management Information Services (including Univac 1108 Remote Terminal Operations)
7. Scientific - Technical Editorial Services
8. Simulation of Effects of Different Types of Crashes on Living Human Bodies

A description of the work performed by QEI personnel in each of these task areas is given in the following discussion.

In connection with the Horizontal Accelerator Studies, QEI personnel performed data analysis, programming and data processing in a number of subareas. A Three Dimensional Transformation Program to transform scaled sensor and photographic data from one coordinate system to another was designed, written and debugged, after which it was subjected to extensive operational testing which detected some additional errors. This program was later modified to handle the new Easy-Flow input. A Runge-Kutta Integration Program to assist in three dimensional tracking was developed, written and debugged after which it was subjected to operational testing and declared verified. An X-ray Anthropometry Input Program to scale digitized x-ray data was designed, written and debugged and all available x-ray data were processed by this program. This program was later expanded and modified to encompass digitization of anthropometry x-rays via a Wang 700 programmable calculator, generation of data for each subject relating instrumentation origins to respective head and neck origins and preparation of an x-ray

data tape in suitable format for further processing. This program is now in production status and all available x-ray data on human subjects have been processed.

A Conversion/Scaling Program and a Random Access Program have been designed, written and debugged and then used for production runs by QEI personnel. A Dynamic Response Study on the effects of onset and duration on the human test subjects was initiated to improve understanding of the human body's reaction. Separate studies on two different subject groups were undertaken to determine the effects of dynamic response to onset and duration. All data on the reactions of the two groups of subjects have been processed and analyzed. A Horizontal Sled Test Report Program was designed, written and debugged and has since been used to process data produced for all the available sled runs. A Regression Analysis Program for Peak Rotational Acceleration and Velocity data producing numerous scatter plots was adapted and made operational and has since been used for many production runs including some runs derived from the Dynamic Response Study on the effects of onset and duration. A Human-Beam Plot Program to compare average human response to dummy response to impact acceleration has been designed, written and debugged and is operational. A Principal Component Analysis Program to identify reproducible waveforms in the acceleration data for the neck has been adapted and made operational. A Spectral Analysis Program to calculate spectral estimates of sensor or derived parameters and to produce plots of power spectral estimates was developed, written and debugged and has been used for

production runs. An Initial Conditions Study to check out photographic data for certain runs was performed and correlations with target-generated photographic data have been verified. An algorithm was devised to align a group of signal vectors and this algorithm has been implemented in a Signal Vector Alignment Program. This program has been written and debugged and has now undergone operational testing, yielding much information concerning initial conditions, correlation of signals and comparison of signals. This program was modified by the addition of a routine to prepare transformed variables for input to the program. Four different transformed runs were input to the program and the resultant outputs were analyzed statistically and by regression techniques. A Filter Routine for Horizontal Sled Accelerometer Data using the output of the Spectral Analysis Program has been designed, written and debugged. This filter routine has been incorporated into the variables program as a selectable option. The routine has been used to filter all runs used for the Dynamic Response Study - Effects of Onset and Duration and to filter certain photographic variables. A program has been designed, written and debugged to model in two dimensions the motion of the human neck and head under impact acceleration. This Model of Neck and Head Program ("MONAH") determines displacement and velocity dependent force constants and intercept angles which in the least squares sense accommodate the forces causing neck and head motion under impact acceleration. The constants produced by this program have accurately described neck and head motion during acceleration. A program has been designed, written

and debugged to sort records and retrieve information from the master tape produced by the History Report Program. A program has been designed, written and tested for the calculation of the locations of a hinge point in the neck anatomical coordinate system and of one in the head anatomical coordinate system such that these hinge points best fit the data from the + Gy impact acceleration runs. (See Appendix A for a summary of two-dimensional modeling of impact acceleration).

Three programs were developed, written and debugged to process, analyze and plot EKG data. These programs are: EKG Raw Data Plot Program, EDG Detection Program (or the EKG Wave Form Recognition and Analysis Program) and EKG Analysis Plot Program. The EKG Raw Data Plot Program produces non-base line corrected X, Y and Z channel plots of digitized EKG data with grids indicating the amplitude and time of the data. Three optional filters, selectable singly or in combination by the programmer, are available if filtered data is desired. The EKG Detection Program filters the data if desired, and then detects the onset, peak and offset of the P-wave, QRS complex and T-wave and the onset and offset of the S-T segment. The EKG Detection Program has been written to allow for adjustment of the detection criteria, useful in compensating for variations in the amplitude of the raw EKG digital data. The EKG (Analysis) Plot Program orders the parameters generated by the EKG Detection Program and establishes the boundaries in time within the data and the upper and lower thresholds for the data. Missing data are calculated by extra-

polation and inserted. Then the plots themselves are produced. The three program set of EKG Analysis Programs has been extensively tested, corrections being made where necessary, and is now fully operational. Programs have also been designed and written first to generate a baseline-corrected averaged PQRST wave form epoching on the R wave onset and second to cross-correlate this averaged wave with each of the PQRST complexes occurring after the sled firing. The debugging and checkout of the Average Wave (AVGWV) Program and of the Cross-Correlation (XCORR) Program have been completed and these programs have now been integrated into a modified version of the EKG Detection Program.

Photographic data from the Sled Run Motion Pictures have been digitized by QEI personnel for a large number of sled runs on humans and on animals and of head nods. A three-day accuracy/reliability test of data was performed using a dummy run as input. Hardware problems have been encountered occasionally, but have been successfully dealt with as the work has progressed.

Forms to use in transcribing medical history data were designed to include all relevant information. Then the information on all these forms up through the latest sled runs has been keypunched and microfilmed. A program has been written and tested to analyze the medical history data and generate a report on each subject. This program is now fully operational.

Forms have been designed for use in recording data for the Blood Chemistry Data Base and the completed forms have then

been keypunched. Programs for editing and updating the Blood Chemistry Data Base have been designed, written and debugged and are now operational. A program to produce a summary report on the Blood Chemistry Data Base has also been designed, written and debugged. A program to calculate statistics on the Blood Chemistry Data has been developed, written and debugged and statistics were calculated for the updated Blood Chemistry Data Base.

A number of Management Information Services were also performed by QEI personnel. Sources of fiscal information were delineated and collated and the system of charges made under the Support and Loan Agreement with the Naval Aerospace Medical Research Laboratory was reviewed and suggestions and recommendations were made. Expenditures in various categories were projected and procedures were established for continuous monitoring of expenditures in relation to the current budget. The remote terminal operations on the Univac 1108 have been continually monitored with a view to spotting errors caused by system malfunction.

QEI personnel have also engaged in scientific - technical editorial services for NAMRL. The final typing, photography and editing was performed on several scientific papers.

Work continued to validate the computer program begun previously to simulate escape system trajectories. This program was updated and modified to simulate several different types of ejection seats. The trajectory simulation program was used to conduct a computer study, requested by the Navy Accident

Investigation Board, of an accident involving an ejection seat. Another computer study was performed, also requested by the Navy Accident Investigation Board, of a second accident involving an ejection seat. Computer predictions were obtained for a track test being conducted on an ejection seat. Assistance was given in preparing a paper on the computer model of the response of a living human body to crash situations. This paper discusses the effectiveness of mathematical models of the human body's reactions.

Several programs to analyze and process EEG Data were designed, written and debugged, including an EEG Linear Model Program, an EEG Data Sorting Program, a Two Dimensional Plot Routine for EEG Data, and a driver for a Time Series Analysis Program for EEG Data. A Cluster Analysis Program and a Raw Data Sorting Program were also adapted and debugged.

The work described above has been carried out under the direction and supervision of the NAMRL director and staff. All data, reports, computer programs and documentation generated in the course of the work have been delivered to NAMRL and are available in the Laboratory files. In Section 5.0 of this report we provide a listing of QEI reports, working papers and memoranda generated under this contract. These can be consulted if more details on the QEI research and support effort are desired.

4.0 SUMMARY OF MEDCON MODEL DEVELOPMENTS FOR NAVY MEDICAL AND HEALTH CARE CONTINGENCY PLANNING

This section summarizes the results of a study conducted under this contract for NAVY-BUMED in support of on-going investigations to determine the optimum model to be used to derive NAVY medical and health care contingency requirements.

Included in the study was an investigation of existing health care models and a review of modifiers and factors which apply. Based on the findings made in the study and on guidelines provided by BUMED, requirement and capability formulas were derived, with the appropriate modifiers which apply to the factors involved. A requirement model was then developed as a set of operational computer programs (The MEDCON Model). The programs developed reflect the workload aspect of medical and health care requirements and include a variety of conversion capabilities.

The operational MEDCON model was substantiated and tested and used to conduct a variety of tests of factor sensitivities. The software has been checked and operated on NAVY computer facilities available to BUMED.

The following items summarize the major accomplishments achieved in the MEDCON study project.

1. A review of existing and available doctrine, models and data pertaining to medical and health care needs of interest to NAVY-BUMED.

2. Derivation of requirement and capability formulas capable of producing time care units for medical and health care needs and applicable within the NAVY-BUMED guidelines.

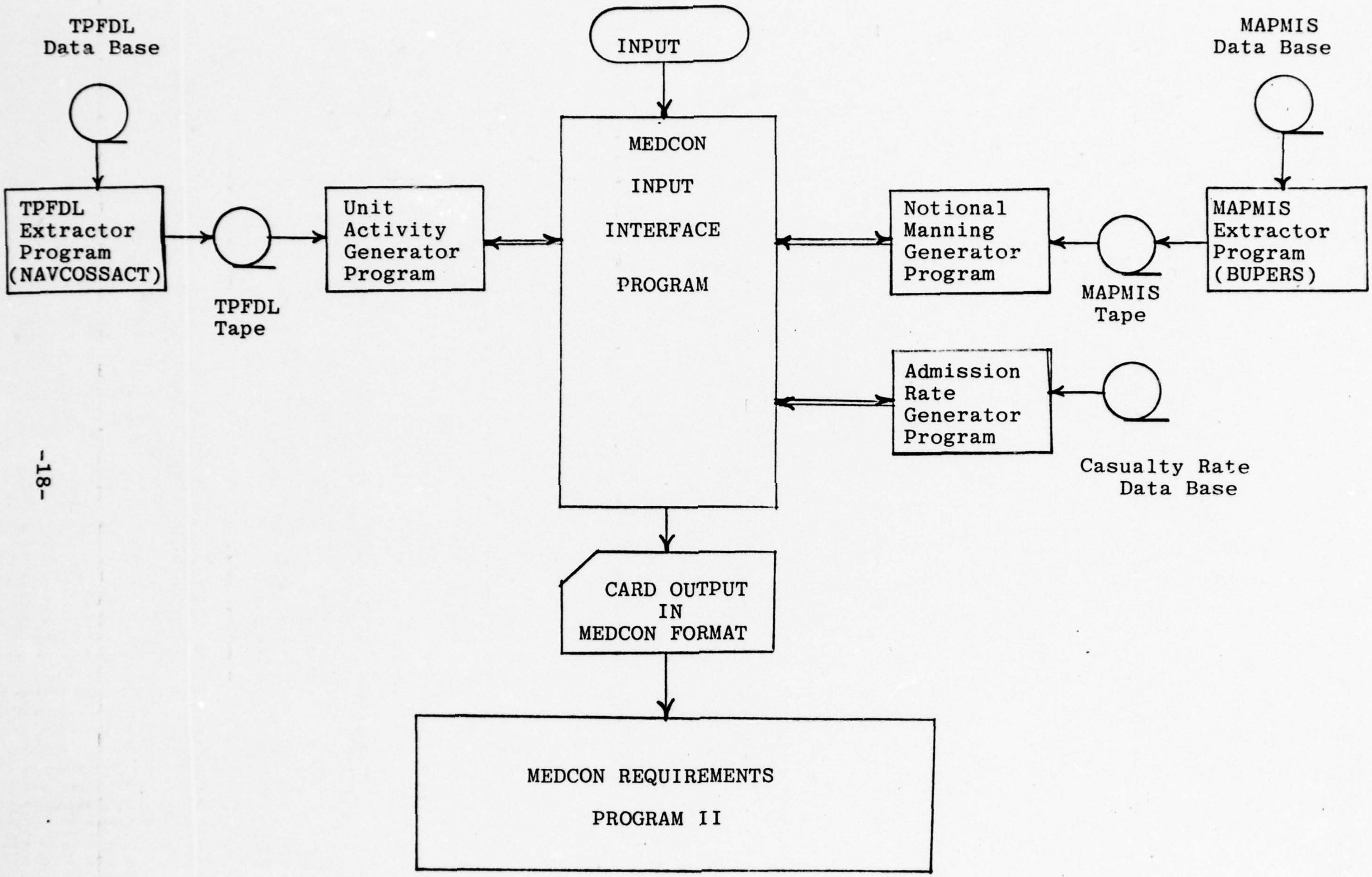
3. Identification of factor variances and modifiers to be applied to requirement and capability formulas for the NAVY contingency situation.

4. Development and implementation of a basic computer model (MEDCON model) incorporating the basic requirements formula.

5. Substantiation and testing of the basic MEDCON model with appropriate data provided by NAVY-BUMED.

A full discussion of the MEDCON mathematical model is given in QEI Report 5131. A description of the basic MEDCON model is also given in Appendix B of this report. Items delivered to NAVY-BUMED under this project included reports and working papers as listed in Section 5.0 of this report as well as a fully operational software package for the MEDCON model including documentation and operating instructions.

Following the development and testing of the basic MEDCON model a MEDCON Extension Study was undertaken to improve and automate both the input and output processes of the basic MEDCON Requirements Program. It was the purpose of this phase of the work to eliminate the lengthy and laborious manual computation and preparation required to provide the input data for the MEDCON Requirements Program. Figure 1 is a diagram which shows the types of input data required for MEDCON. In the MEDCON Extension Study the Manning Generator Program, the MAPMIS Extractor Program and Admission Rate Generator Program were implemented and tested. Although work on the TPFDL Extractor Program was begun this was not completed because of problems associated with the restrictions on the availability of the classified source data. The work and



Automation of Input for The MEDCON Model
Figure 1

results of the MEDCON Extension Study are discussed in QEI Reports 5131 and 5915. Examples of some of the MEDCON output data are illustrated in Appendix C of this report.

5.0 LIST OF QEI REPORTS, WORKING PAPERS AND MEMORANDA GENERATED UNDER THIS CONTRACT

5.1 Items Relating to the Impact Injury Prevention Program

QEI Item or Report No.	
IM-09-Dec-69-1	List of Symbol Definitions
IM-12-Dec-69-1	Outline of QEI First-Phase Effort on -G Impact Acceleration Studies
IM-22-Jan-70-1	Kinematics of Isolated Points on a Rigid Body
IM-11-Jan-70-2	Spectral Structure of Accelerometer Input
IM-28-Jan-70-1	Computer Program for Spectral Structure of Accelerometer Input
IM-30-Jan-70-1	List of Articles QEI has received on Impact and Acceleration Studies
IM-03-Feb-70-1	Status of FFT Signal Analysis and Results to Date
IM-04-Feb-70-1	DSCALE Program
IM-05-Feb-70-1	Time Skew A/D Conversion
IM-06-Feb-70-1	HICEPT A/D Conversion Program: BETHBH
IM-17-Feb-70-1	Data Sort Program BETH02
IM-08-Apr-70-1	Reclarification of Task Areas
IM-08-Apr-70-2	Network Illustrating Tasks for Impact Acceleration Project
IM-13-Apr-70-1	Machine Independent Programming for the Impact and Acceleration Study
IM-13-Apr-70-2	Analog-To-Digital Conversion Facilities Survey
IM-15-Apr-70-1	Data Sort Programming for the Impact and Acceleration Study
IM-15-Apr-70-2	Description of ICONDS Program
IM-11-Jun-70-1	Digital Sampling of Tape Run H-036
IM-12-Jun-70-1	Further Power Spectrum Analysis of Runs H-036, H-054, and H-232

QEI Item or Report No.	
IM-18-Jun-70-1	Euler Angle Transformations and Quaternions
IM-13-Jul-70-1	Experimental Design and Characterization of Human Response
IM-29-Jul-70-1	Verification Procedure for A/D Conversion System
IM-06-Aug-70-1	Power Spectrum Analysis of Reconverted Data from Runs H-036, H-054, and H-232
IM-12-Aug-70-1	Tape Specifications and Comparisons
IM-18-Aug-70-1	Effect of Accelerometer Positions on Acceleration Measurements
IM-26-Aug-70-1	Experimental Run Comments
IM-31-Aug-70-1	Equations for Mapping Acceleration Contours Using Four Accelerometers at Four Locations
IM-08-Sep-70-1	Degeneracy and Redundancy in Acceleration Measurements
IM-01-Oct-70-1	General Linear Analysis of the Head/Neck System
IM-02-Oct-70-1	OUTVAR, The Output Variables Program
IM-14-Oct-70-1	The G-Amplification Factor
IM-15-Oct-70-1	Comparison of Rate Gyros Versus Accelerometers
IM-23-Oct-70-1	Pre-Calculations for 3-D Motion Analysis
IM-01-Nov-70-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-13-Nov-70-1	Quaternion Algebra and Rigid Body Rotation
IM-30-Nov-70-1	Quaternion Derivatives and Angular Velocity
IM-08-Dec-70-1	Linear System Modelling and Certain Related Problems
IM-09-Dec-70-1	Continuation of the Linear Analysis of the Head/Neck System (Frequency Domain)
IM-09-Dec-70-2	Problems in Characterizing the Head/Neck System in a Linear System
IM-10-Dec-70-1	An Interim Working Paper on System Error Analysis

QEI Item or Report No.	
IM-31-Dec-70-1	3-D Data Simulation - Memo A - Overview and First Steps
IM-28-Jan-71-1	Mathematical Modelling for Head and Neck Under Impact Accelerations
IM-29-Jan-71-1	3-D Data Simulation - Memo B - Coordinate System Conventions and Misalignment Corrections
IM-02-Feb-71-1	RGDIV, The New Version
IM-15-Feb-71-1	Simulation Studies to Support System Error Analysis
IM-04-Mar-71-1	3-D Simulation - Memo C - A Simple Trajectory for Exercising the 3-D Simulation
IM-08-Mar-71-1	Vertical Mount Pendulum
IM-02-Apr-71-1	Preliminary Computer Results of Accelerometer Phase-Lag Error
IM-12-Apr-71-1	Ideas for Future Work on Impact Studies
IM-01-May-71-1	Semi Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-01-May-71-2	Documentation of Program OUTVAR
IM-13-May-71-1	Tentative Up-Dated Pert-Chart - May 1971
IM-02-Jun-71-1	Additional Output Variables
IM-03-Jun-71-1	Center of Rotation Data
IM-07-Jun-71-1	Mathematical Modelling - First Order Effects (A Progress Report, up to 1 June 1971)
IM-19-Jul-71-1	3-D Simulation - Memo D - Equations for the Three-Rate-Gyro/Three-Accelerometer Configuration
IM-03-Aug-71-1	Improved Modelling Considerations
IM-31-Aug-71-1	3-D Simulation - Memo E - Six Accelerometer Data Reduction
IM-08-Oct-71-1	Methodologies for Selection of Parameter Values in Experiment Design
IM-29-Oct-71-1	3-D Simulation - Memo F - Conversion of Euler Angles from One Coordinate System to Another

QEI Item or Report No.	
IM-29-Oct-71-2	Analysis of Geometric Relations Between Previously Defined Coordinate Systems and Anatomically Referenced Coordinate Systems as Implemented in Program TROUT
IM-01-Nov-71-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-23-Nov-71-1	A Description of the Output Variables Program, OUTVAR
IM-10-Dec-71-1	3-D Simulation - Memo G - Preliminary Thoughts on "Neck Stretch" in Three Dimensions
IM-13-Jan-72-1	Simulated Data for OUTVAR and TROUT
IM-17-Jan-72-1	3-D Simulation - Memo H - Application of the 3-D Analysis to the 2-D Case to Obtain Location and Alignment Corrections
IM-24-Feb-72-1	OUTVAR Tested
IM-29-Feb-72-1	Error Study of the Collocation Corrections
IM-24-Mar-72-1	Program TROUT Tested
IM-14-Apr-72-1	Program TROUTP Changed and Tested
IM-24-Apr-72-1	3-D Simulation - Memo I - Conversion from Euler Angles to Great Circle Arcs
IM-16-May-72-1	Suggested Project Standards for Computer Variables (Preliminary)
IM-18-May-72-1	Preliminary Program Considerations for Scaling Vertical Accelerator Data
IM-23-Jun-72-1	Main Flow Chart of Program OUTVAR
IM-26-Jun-72-1	Updated Flowcharts for Program OUTVAR
IM-30-Jun-72-1	Semi Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-10-Jul-72-1	Contribution to Impact Acceleration Report
IM-14-Jul-72-1	Draft of Material Concerning Program TROUT for Impact Acceleration Report
IM-19-Jul-72-1	Program TROUT Flow Diagrams

QEI Item or Report No.	
IM-21-Jul-72-1	Program TROUTP Flow Diagrams
IM-21-Jul-72-2	Program TROUTH Flow Diagrams
IM-22-Jul-72-1	Draft of Material Concerning Validation of OUTVAR, TROUT, TROUTP and TROUTH for Impact Acceleration Report
IM-26-Jul-72-1	Draft of Material Concerning Programs TROUTP and TROUTH for Impact Acceleration Report
IM-28-Jul-72-1	Draft Material for Impact Acceleration Report
IM-31-Aug-72-1	Subroutines Implementing the Algorithms in Program TROUTP
IM-07-Sep-72-1	Status Report on Vertical Acceleration Data Processing
IM-12-Sep-72-1	G-Level and Bandwidth Prediction - Preliminary Concepts
IM-01-Nov-72-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-07-Nov-72-1	3-D Simulation - Memo J - Special Six Accelerometer Configurations
IM-10-Nov-72-1	Status Report on Vertical Acceleration Programming
IM-20-Nov-72-1	Punch Card Format for Entering Peak Strain Data of W.S.U. Vertical Acceleration Tests Into DSCALE Program
IM-26-Dec-72-1	Revised Punch Card Format for W.S.U. Strain Data
IM-15-Jan-73-1	Three Dimensional Perspective Plotting Routines
IM-12-Feb-73-1	Suggested Regression Analysis of Head and Neck Response to Impact Acceleration
IM-14-Feb-73-1	Documentation including Flowcharts for the DSCALE Program for Vertical Acceleration Data Processing
IM-28-Feb-73-1	Documentation including Flowcharts for the CHNGVR Program for Vertical Acceleration Data Processing
IM-11-Mar-73-1	Clarification of DPTZ as used in Vertical Acceleration Program DSCALE

QEI Item or Report No.	
IM-23-Mar-73-1	Vertical Acceleration Runs - Using Peak Strain Data to Check DSCALE Program Results
IM-20-Apr-73-1	Air Crew Injury Data Base and Query System
IM-27-Apr-73-1	Extending the Query System for the Air Crew Injury Data Base to Cover Data Bases for Two- and Three-Dimensional Impact Acceleration Studies
IM-22-May-73-1	Vertical Acceleration Runs - Analysis of Peak Strain Data Versus Peak Values from DSCALE Program - Preliminary Analysis
IM-01-Jun-73-1	3D Photogrammetry - Memo A - Some Basic Equations for X-Ray and Optical Anthropometry
IM-25-Oct-73-1	3D Photogrammetry - Memo B - Some Methods of Calibration and Data Reduction in Optical and X-Ray Photogrammetry
IM-01-Nov-73-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-01-Nov-74-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-01-Nov-75-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-01-Nov-76-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program

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IM-01-Nov-74-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-01-Nov-75-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program
IM-01-Nov-76-1	Annual Report: Joint Army/Navy Air Crew Impact Injury Prevention Program

5.2 Items Relating to the MEDCON Model Development Program

QEI Item or Report No.	
A-1025	MEDCON Study Model
A-1031	The Workload Formula
A-1111	MEDCON Study Model (Revised)
A-1112	The Requirement Formula
A-1114	The Capability Formula
C-1120	Some Relationships Between Bed Requirements, Accumulation Factors, and Efficiency
A-1122	Types of Data and Formats QEI Will Require for the MEDCON Study
A-1129	The Requirement Formula (Revised)
A-1130	The Capability Formula (Revised)
C-1213	A Note on the Accumulation Factor and Average Length of Stay
C-1220	A Discussion of the Dispersion Factor in the Computation of Health Care Requirements
A-1224	MEDCON Study Model (Revised)
A-1226	The Requirement Formula (Revised)
A-1227	The Capability Formula (Revised)
C-1228	Simulation of Navy Health Care System for Contingency Operations
A-1230	A Note on the Effects on Requirements Caused by Changes in the Casualty Rates
A-1231	Note on Changes Over Time in Definitive Bed Requirements
Report 5131	Development of a MEDCON Model for Medical and Health Care Contingency Requirements Planning, January 31,1975.
Report 5331	Description of the MEDCON Model Requirements Program II, March 31, 1975.
Report 5915	Development of Input Processes for MEDCON Requirements Program II, October 15, 1975.

APPENDIX A

TWO-DIMENSIONAL MODELING OF IMPACT ACCELERATION

TWO-DIMENSIONAL MODELING OF IMPACT ACCELERATION

Modeling Requirements

A well-conceived model must meet at least the following conditions:

(1) The basic mechanical structure of the model must be equivalent to real life. This means the model is capable of reproducing the same motions. Whether it will or not, then depends on the proper setting of the parameters but at least the structure must be capable of reproducing the motion.

(2) The degrees-of-freedom of important objects such as the head, the neck, and pelvis must be the same in the model as in real life. In two-dimensions there are three degrees-of-freedom (x,y,θ) for each of these objects.

(3) Provision must be made for putting real data into the model at the appropriate point.

(4) Provision must be made for getting output data from the model and comparing this data with actual measured data to verify, reject, or improve the model.

(5) Some, if not all, of the important parameters must be equal in real-life and in the model. For example, mass of the head, moments-of-inertia, neck length, neck stretch, neck angle, head angle, head displacement, internal forces and stresses, peak torques and accelerations, angular velocities, and the times to peak displacements and accelerations.

Overall Modeling

To place the head-and-neck model in perspective, consider Figure 1. Consider the primary input to be the acceleration profile of the sled. The sled represents the real-life vehicle.

Mounted on the sled is a seating structure for the man. This seating structure represents the seat in a real vehicle. The seating structure has its own dynamic response to the motion of the sled. The resonances of the seat structure should be measured under the various man-weight loads and sled accelerations.

Between the man and the seat is a padding-and-harness-restraint system. The straps will have various elastic constants and the padding will have a certain compressibility. These parameters also affect the accelerations sustained by the subject.

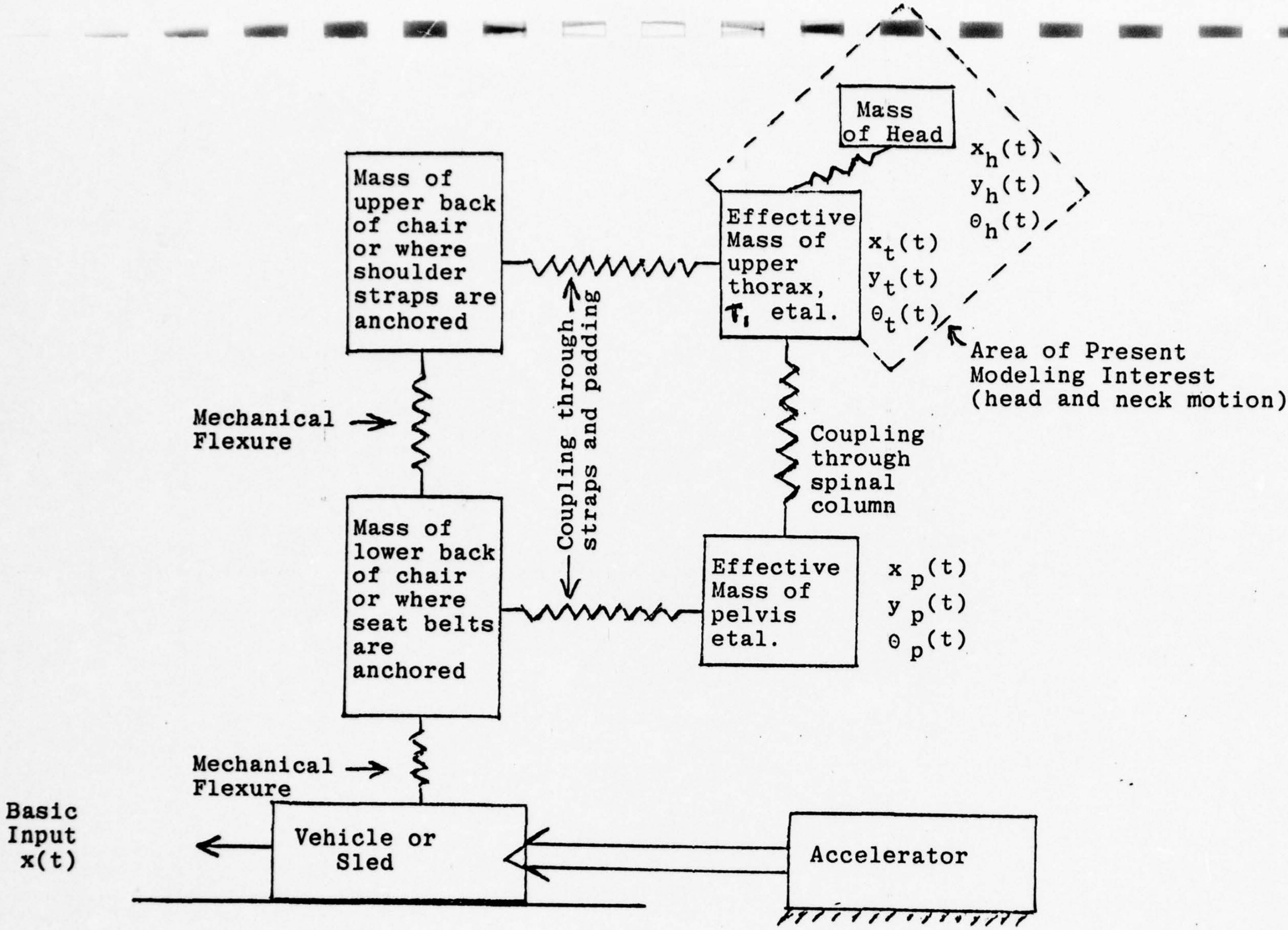

FIGURE 1

Simplified Sketch of Overall Modeling Problem

Another set of variables which are important but difficult to measure properly are the exact initial conditions. These include the tensions in the various straps, the pressure angles at which these straps exert forces on the various parts of the body. These, of course, vary from individual to individual because of differences in body size and shape.

A problem of this degree of complexity and variability must be broken down into manageable subsystems and certain simplifying assumptions must be made. The subsystem we are concerned with here is the head-and-neck subsystem. The simplifying assumption is that the head and top of the thoracic cage behave as two separate rigid bodies. The top of the thoracic cage is held effectively in place by the shoulder strap and its motion is assumed to be measured at T_1. The head and skull can be considered a rigid body and its motion in inertial space depends only on linkages in the neck. Most of these linkages terminate on the top of the thoracic cage. Under impact conditions it is assumed that motion of the top of the thoracic cage is adequately measured by the motion of the first thoracic vertebra and that the motion of the head is adequately determined only by this T_1 motion.

Dynamic Equations The head is to be modeled as a rigid body. It has three degrees-of-freedom of motion in the plane, namely x-position, y-position, and angular position θ.

It obeys three simple laws of mechanics, the sum of the x-forces gives the x-acceleration, the sum of the y-forces gives the y-acceleration, and the sum of the torques gives the angular acceleration. In equation form these laws can be written as

$$m\ddot{x} = \sum f_x \equiv F_x \tag{1}$$

$$m\ddot{y} = \sum f_y \equiv F_y \tag{2}$$

$$J\ddot{\theta} = \sum T_i \equiv F_\theta \tag{3}$$

where m is the mass of the head, J is the moment of inertia about the center of gravity of the head and $\ddot{x}, \ddot{y}$ are the accelerations of the center of gravity in inertial space. A sketch of the model is given in Figure 2.

The above laws are immutable and apply to any material aggregate moving in concert in terrestrial (non-relativistic) experiments. Engineering judgement along with physical and anatomical considerations are now required in assigning the most appropriate formulas for F_x, F_y and F_θ.

Because we are interested in the motion of the head at higher g-levels (10g's and up in the midsagittal plane) we shall neglect

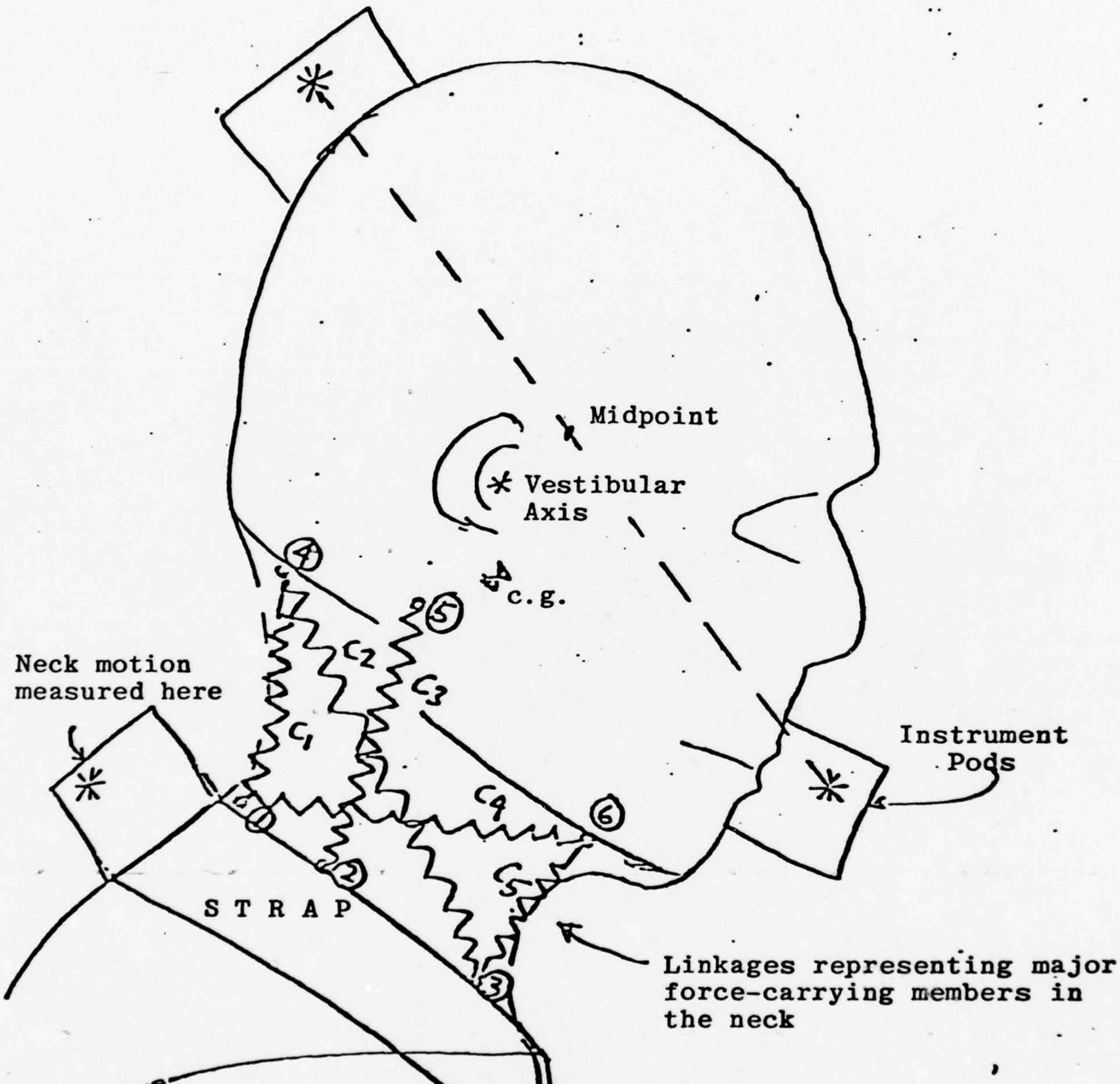

FIGURE 2

Sketch of Head-and-Neck Model
(illustrative only)

the force of gravity. Hence, all the forces contributing to F_x, F_y, and F_θ come through the neck and in fact only through those points of substantial attachment of the neck to the head.

At this point in the development of this model it would be well to examine the anatomical structure of the neck to locate the position of attachment of the main force-carrying members in the neck. When such a study of the neck structure is made it can be incorporated in the model without upsetting the basic operating principles of the model.

The Neck Motion (T_1) as Input The driving input to the head is the neck motion which is measured at T_1. The model must and does incorporate a means of applying this measured motion as input to the model.

It is logical to assume that the forces acting on the head through the joints, tendons, and muscle structure of the neck are functions of the displacement of the head (from its normal equilibrium position) relative to the neck. These functions will doubtless be non-linear but in all probability they can be approximated by a linear, square-law, polynomial or other simple mathematical form which will be adequate for the range of forces and displacements of interest.

The forces on the head resulting from head-neck displacements will probably be also a function of the neck angle, and possibly a function of other variables including time. A term proportional to the relative velocity between head and neck can be used to simulate the natural damping effects.

Initial Conditions It is known that the peak-acceleration sustained by the mouth in a given experiment depends on the initial position of the head. For this reason the model will include provisions for varying the initial head-angle and neck-angle, as will be required to verify the model using various experimental runs.

Head-Nod Data Included To keep the model realistic, head-nod data will be incorporated in the model so that displacement of the head from its equilibrium position can be correctly ascertained as a function of neck-angle. Only differences between the dynamic head position and the head-nod position at that angle will be used in the force equations.

Replication of Measured Data A preliminary flow graph for exercising the model is shown in Figure 3. The input is the measured neck-motion data streams from a recorded run. The output is a replication of the head angular velocity and acceleration which can be compared with the measured values of these quantities to verify the model. The comparison of acceleration data can be made at the center of gravity of the head or at the actual transducer locations. Hence, the model can be verified by showing that it reproduces measured accelerations at the mouth and bregma.

Application to Dummy Design When the force functions (F_x, F_y, F_θ) have been verified, a spring-and-linkage mechanism can be designed which will reproduce the motion of the head under impact conditions. This spring-and-linkage mechanism can then be incorporated in an anthropomorphic dummy for simulating motion of head and neck in the mid-sagittal plane.

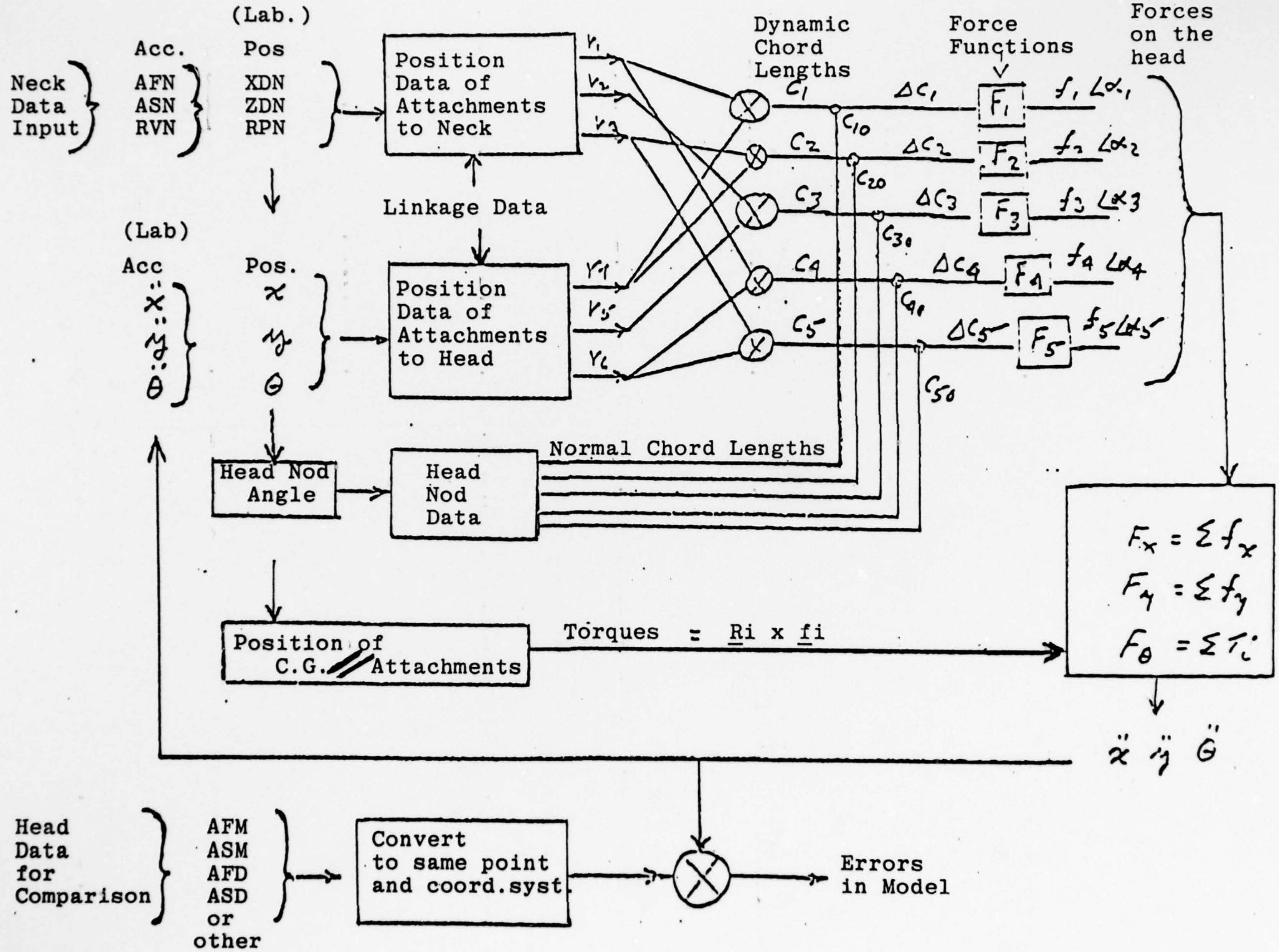

FIGURE 3

Preliminary Flow Graph for Exercising and Verifying Model

APPENDIX B

DESCRIPTION OF THE BASIC MEDCON MATHEMATICAL MODEL

The problem addressed by the MEDCON study can be described in a flow diagram showing the movement of casualties through the Navy Medical System and indicating flow rates and divisions of flow. The basic model for the MEDCON study problem is a queueing model with the following three elements: 1) a requirement formula to produce the medical requirements or workload of each facility in the Navy Medical System in time-care units; 2) a capability formula to estimate the capability in a specified medical contingency of each facility in the Navy Medical System in time-care units; 3) a mechanism for combining and/or comparing requirements and capability, such as a requirement/capability ratio. This model provides an approximate determination of the overall adequacy of the entire Navy Medical System for handling all medical contingencies described by the given scenario. However, it should be pointed out that this model permits an exact determination of the requirements or capabilities of an individual Navy Medical installation or facility only if precise complete detailed information on that facility is available. The basic model is concerned with the capabilities needed at all Navy Medical facilities to cope with the overall requirements during a contingency described by the given scenario, rather than with the match between an individual Navy Medical facility and its requirements.

The general flow diagram of the problem shows the movement of casualties through the Navy Medical System. This flow diagram

includes the rates of flow for all casualty flows and, in situations where a flow is divided into two or more parts, shows the proportions into which the total flow is divided. This general flow diagram includes all casualty flows which can occur at any stage or time period of the mobilization or actual hostilities. (Whenever a certain flow does not occur, its rate of flow is made zero.) A general flow diagram is shown in Figure 1.

The specific flow diagrams are specifications of the general flow diagram to one particular point in time, but should include the casualty flows for all geographical locations where hostilities are occurring at that time. The entire collection of specific flow diagrams presents all the casualty flows for all included geographical locations at all the selected time points in the mobilization process and during actual hostilities.

Each Navy Medical facility in the system can be considered to be a service facility at which casualties queue up. Thus, queueing theory can be applied to the analysis of the operation of each Navy medical facility and thus to the analysis of the entire system.

Each Navy Medical facility can be considered to have a single entrance channel with many servers or many Navy medical personnel providing service to the casualties. Casualties of each type will arrive at each Navy medical facility at a rate determined by an input probability distribution which is unique to each type of facility and patient type. However, because of the fact that

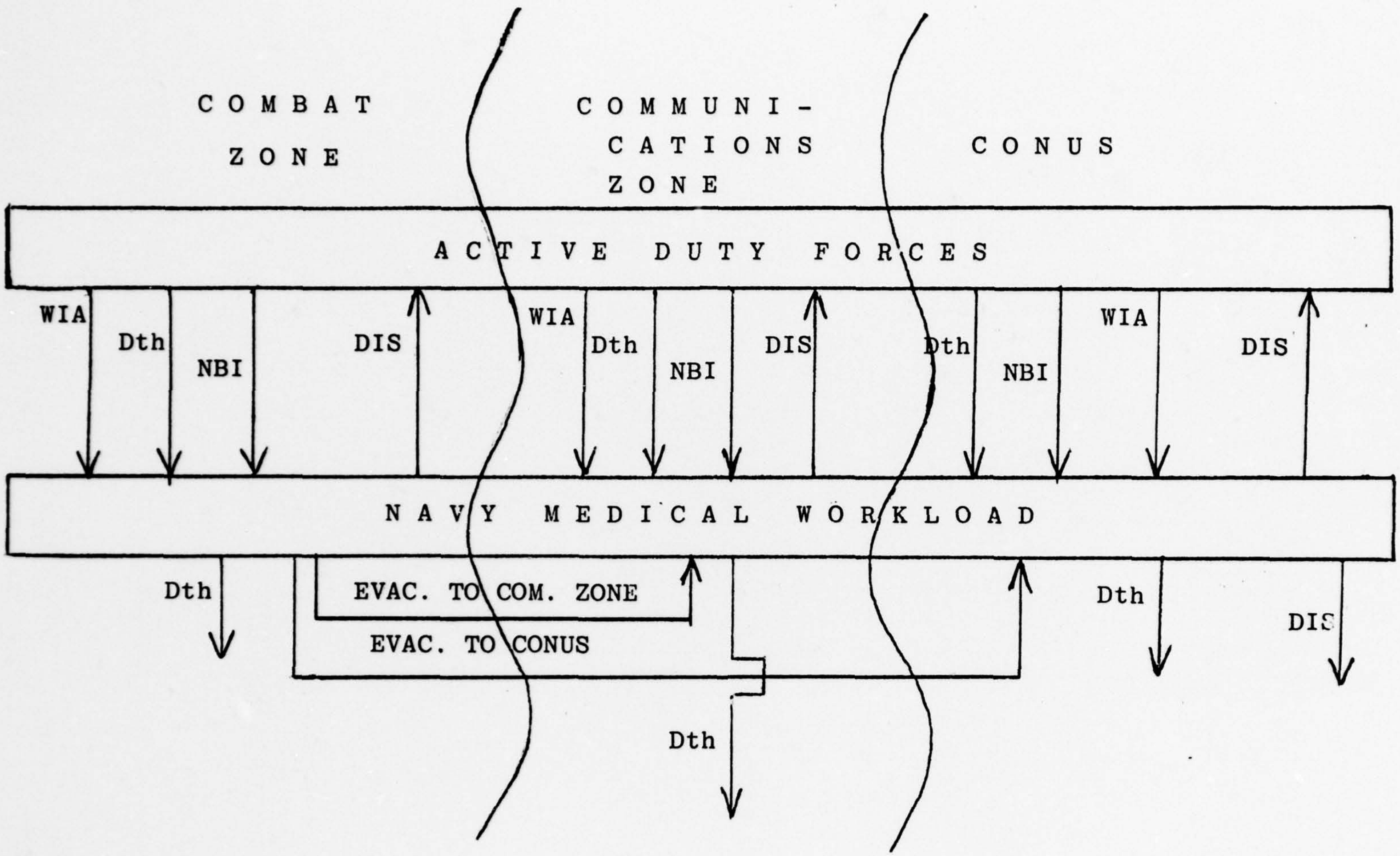

Figure 1

General Flow Diagram for MEDCON

each Navy medical facility will have the capacity to provide multiple servers in expansible numbers, it can be assumed that the waiting time in the queue for each casualty will be very short or virtually zero. It can be assumed that each Navy medical facility will have sufficient capability and capacity to start providing services to the incoming casualties almost as soon as they arrive (in all but highly improbable cases). The queue discipline is not usually established but this is unimportant due to the fact that each casualty is served immediately.

Each Navy medical facility also has an associated service time probability distribution for each casualty type which gives the length of stay of the patient type. This service time distribution is unique to the particular facility and will change over time according to the rate at which casualties enter the system, because of decisions (such as the evacuation policy) made by the personnel at the facility or by Navy line commanders. This service time distribution for each casualty type for all overseas Navy medical facilities is characterized in part by the fact that it has upper and lower bounds above and below which the probability will be zero. The upper bound for the service time distribution for each casualty type at a particular facility is established by the limit imposed by the evacuation policy at that time. The lower bound for the service time distribution for a certain casualty type at a particular facility is established by the minimum number of days needed to stabilize a patient with that type of injury or wound. Changes in the limit established by the

evacuation policy in effect change the character of the service time distribution and its associated statistics such as the mean and the variance.

When a patient leaves a particular Navy medical facility or service installation, he can either enter the queue for another Navy medical facility if he is evacuated, or he can leave the Navy medical system entirely by returning to duty, being discharged or dying. Thus, the entire Navy medical system can be considered to be a queueing system of service facilities operating in parallel lines with the provision that each patient upon leaving one facility can enter another facility in the system or can leave the system entirely according to the seriousness and type of his injuries.

The requirement formula applied to a particular time and location (or equally a particular facility) gives the average rate at which beds will be required for casualties or input that enter the queue to be served at the facility, assuming that the facility is in a steady state or operating under conditions of equilibrium. The capability formula applied to a particular facility and time determines the values of the service distribution for each patient type for that facility minus the alteration imposed by the upper bound derived from the current evacuation policy. The comparison of the outputs from the requirement and capability formulas for a particular facility and time will determine if the capability of the facility should be altered or if the evacuation policy should be changed or if more transportation should be provided.

The requirement formula produces the medical requirement in time-care units for one particular day during mobilization or actual hostilities for one particular naval entity. The requirement formula operates on the given troop strengths, the historical admission rates, estimated accumulation factors and estimated dispersion factors, these estimates being derived largely from historical data. The requirement formula is of the form:

$$\text{Requirement} = \text{Troop Strength} \times \left[\sum_{i} (\text{Admission Rate})_i \times (\text{Accumulation Factor})_i \times (\text{Dispersion Factor})_i \right]$$

where the summation is over the index i representing different types of casualties - Wounded in Action (WIA), Disease (D), and Non-Battle Injury (NBI). The basic form of the requirement formula is independent of both time and location.

The requirement formula is used to compute a matrix of requirements for each relevant time and location. A two-dimensional matrix of requirements is produced with rows representing all relevant times and the columns, all included locations. For facilities outside of CONUS the requirement for location k at time t is equal to the output of the requirement formula for location k, time t.

For facilities in CONUS to which casualties will be evacuated once hostilities start, the requirement for location k at time t is computed by summing the output of the requirement formula for location k, time t (if the Navy sustains casualties at that location) and the requirement generated by all those casualties evacuated to location k between time t-1 and time t. The requirement generated by casualties evacuated to a facility is derived by an application of a slight variant of the requirement formula. (It is assumed

that any casualties that are evacuated will be evacuated to CONUS and not laterally.)

The capability formula produces the capability of a specified part of the Navy Medical System in time-care units for one particular day during mobilization or actual hostilities. The capability formula operates upon estimates of medical personnel numbers and specialities, medical facility capacities and locations, casualty care times, dispersion factors, and logistic requirements, these estimates being derived largely from Navy Medical doctrine, practices, and structure. The capability formula is of the following form:

Capability = (Location and Type of Facilities and Specialities) x (Casualty Care Time) x (Dispersion Factor) x (Logistics Support Factor).

The basic form of the capability formula is independent of both time and location. (A dispersion factor is included in both the requirement and the capability formulas; however, each of these dispersion factors is derived from a different viewpoint and from the consideration of different circumstances and modifiers. However, for one particular time and location these two dispersion factors should be approximately equal.)

The capability formula is used to compute a matrix of capabilities for each included time and Navy medical facility (or location). A two-dimensional matrix of capabilities is produced with the rows representing all relevant times and the columns, all locations of Navy medical facilities. The capability available at location k at time t is the same as that for

location k at time t-1 with any specified changes in capability at location k that occur during the period from t-1 to t being added in.

The mechanism that has been chosen for combining and/or comparing medical requirement and capability at a particular time and location is the requirement/capability ratio. The ratio of requirement to capability was chosen as the basic means of combining and comparing requirement and capability since a ratio is so simple and direct. For each chosen time during the mobilization and actual hostilities the requirement/capability ratio is computed for each location where hostilities occurred. Then the average over location of these requirement/capability ratios, weighted by the troop strengths at the corresponding locations, is computed. This average should be fairly close to 1 for each time point if the Navy Medical System is to have the overall capability to meet the total requirement. The requirement/capability ratio at each location is also examined to detect gross mismatches of capability and requirement at any location. However, even fairly large deviations of individual requirement/capability ratios from 1 can be ignored, since we are principally concerned with ascertaining the adequacy of the entire Navy Medical System. Small deviations in the requirement/capability ratio from the ideal 1 will certainly average out in their effects if the entire Navy Medical System has sufficient capability to meet the requirements at all time points during mobilization and actual hostilities. The determination of the staffing and required facilities for each individual Navy Medical installation is disregarded for the time being in

order to concentrate on the question of the adequacy of the entire Navy Medical System to handle the contingency requirements specified by the given scenarios.

The basic MEDCON model does, of course, operate under certain specific constraints or limitations. These limitations on the model derive from three sources: 1) the interfaces that are necessary with other models; 2) the parts of the data base that are available and usable; and 3) the standard naval medical doctrine. The limitations imposed on this model by the interfaces necessary with other models are those imposed by the range of evacuation policies considered. These limitations must be determined by study of the effects of the scenarios and the evacuation policies on the casualty flows in the Navy Medical System. The limitations imposed on this model by the available data base are principally limitations on the possible classifications of casualties, determined by the remaining historical data on casualties in the data base, and limitations on the accuracy and coverage of the data base. These limitations will, of course, be discovered by a close examination of the data base. The limitations imposed on this model by standard naval medical doctrine are principally the restrictions that military dependents, military retirees, and retirees' dependents are not to be included in any of the planning and calculations, and that foreign civilians and prisoners of war will also not be included in any calculations. Only active duty naval personnel are included in this model and its associated calculations.

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APPENDIX C

Examples of MEDCON Model Computer Outputs

THEATER = 1 EVACUATION POLICY = 2 BATTLE SITUATION = 1

	M-1	M-DAY	D-DAY	D+30	D+60	D+90	D+120	D+150	D+180
DAILY ADMISSIONS FOR INTERVAL FOLLOWING									
WIA									
NAVY ASHORE	0.	0.	3.	4.	4.	5.	5.	5.	5.
NAVY AFLOAT	0.	0.	0.	1.	1.	1.	1.	1.	1.
FMF ASHORE	0.	0.	3.	158.	158.	158.	158.	158.	158.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	0.	0.	7.	163.	163.	163.	164.	164.	164.
DIS									
NAVY ASHORE	9.	10.	12.	14.	15.	16.	16.	16.	16.
NAVY AFLOAT	9.	9.	9.	20.	20.	23.	27.	27.	27.
FMF ASHORE	1.	1.	1.	66.	66.	66.	66.	66.	66.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	19.	20.	22.	101.	101.	105.	110.	110.	110.
NBI									
NAVY ASHORE	8.	9.	12.	14.	14.	15.	16.	16.	16.
NAVY AFLOAT	10.	10.	10.	21.	21.	24.	28.	28.	28.
FMF ASHORE	1.	1.	1.	69.	69.	69.	69.	69.	69.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	19.	20.	23.	104.	104.	109.	113.	113.	113.
GRAND TOTAL OF ALL DAILY ADMISSIONS	38.	40.	52.	367.	369.	377.	387.	387.	387.
ADMISSIONS FOR ENTIRE INTERVAL FOLLOWING									
WIA									
NAVY ASHORE	0.	0.	103.	121.	127.	136.	140.	140.	140.
NAVY AFLOAT	0.	0.	12.	27.	27.	31.	36.	36.	36.
FMF ASHORE	0.	0.	85.	4731.	4731.	4731.	4731.	4731.	4731.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	0.	0.	201.	4879.	4885.	4896.	4908.	4908.	4908.
DIS									
NAVY ASHORE	9.	221.	361.	422.	443.	477.	491.	491.	491.
NAVY AFLOAT	9.	212.	277.	607.	607.	695.	817.	817.	817.
FMF ASHORE	1.	28.	36.	1992.	1992.	1992.	1992.	1992.	1992.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	19.	460.	674.	3022.	3043.	3164.	3300.	3300.	3300.
NBI									
NAVY ASHORE	8.	214.	351.	410.	430.	463.	477.	477.	477.
NAVY AFLOAT	10.	222.	289.	634.	634.	726.	853.	853.	853.
FMF ASHORE	1.	29.	37.	2067.	2067.	2067.	2067.	2067.	2067.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	19.	465.	677.	3111.	3132.	3256.	3397.	3397.	3397.
GRAND TOTAL OF ALL ADMISSIONS FOR THE INTERVAL	38.	925.	1552.	11011.	11059.	11318.	11605.	11605.	11605.

WIA

	M-1				M-DAY				D-DAY			
	MC	NC	MSC	HM	MC	NC	MSC	HM	MC	NC	MSC	HM
NAVY ASHORE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NAVY AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FMF ASHORE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	D+30				D+60				D+90			
	MC	NC	MSC	HM	MC	NC	MSC	HM	MC	NC	MSC	HM
NAVY ASHORE	17.	20.	9.	45.	20.	23.	10.	53.	21.	24.	10.	56.
NAVY AFLOAT	2.	2.	1.	5.	4.	5.	2.	12.	4.	5.	2.	12.
FMF ASHORE	14.	16.	7.	38.	780.	910.	390.	2080.	780.	910.	390.	2080.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	33.	39.	17.	88.	804.	938.	402.	2144.	805.	939.	403.	2147.

	D+120				D+150				D+180			
	MC	NC	MSC	HM	MC	NC	MSC	HM	MC	NC	MSC	HM
NAVY ASHORE	22.	26.	11.	60.	23.	27.	12.	62.	23.	27.	12.	62.
NAVY AFLOAT	5.	6.	3.	14.	6.	7.	3.	16.	6.	7.	3.	16.
FMF ASHORE	780.	910.	390.	2080.	780.	910.	390.	2080.	780.	910.	390.	2080.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	807.	942.	404.	2153.	809.	944.	404.	2157.	809.	944.	404.	2157.

DIS

	M-1				M-DAY				D-DAY			
	MC	NC	MSC	HM	MC	NC	MSC	HM	MC	NC	MSC	HM
NAVY ASHORE	15.	17.	7.	39.	425.	495.	212.	1132.	809.	944.	405.	2158.
NAVY AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	4.	4.	2.	10.
FMF ASHORE	0.	0.	0.	0.	118.	137.	59.	314.	154.	180.	77.	410.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	15.	17.	7.	39.	542.	633.	271.	1446.	967.	1128.	483.	2579.

	D+30				D+60				D+90			
	MC	NC	MSC	HM	MC	NC	MSC	HM	MC	NC	MSC	HM
NAVY ASHORE	879.	1025.	439.	2344.	998.	1164.	499.	2660.	1082.	1262.	541.	2885.
NAVY AFLOAT	5.	6.	2.	13.	10.	12.	5.	28.	10.	12.	5.	28.
FMF ASHORE	250.	292.	125.	667.	284.	331.	142.	757.	284.	331.	142.	757.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	1134.	1323.	567.	3023.	1292.	1507.	646.	3445.	1376.	1605.	688.	3669.

	D+120				D+150				D+180			
	MC	NC	MSC	HM	MC	NC	MSC	HM	MC	NC	MSC	HM
NAVY ASHORE	1166.	1361.	583.	3110.	1167.	1361.	583.	3111.	1167.	1361.	583.	3111.
NAVY AFLOAT	12.	14.	6.	32.	14.	16.	7.	38.	14.	16.	7.	38.
FMF ASHORE	284.	331.	142.	757.	284.	331.	142.	757.	284.	331.	142.	757.
FMF AFLOAT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	1462.	1706.	731.	3899.	1464.	1708.	732.	3905.	1464.	1708.	732.	3905.

BASIC ALLOWANCE FOR EACH MAJOR CLAIMANT CODE

MAJOR CLAIMANT CODE	2100	2200	2300	2900	9000	9200	9500	9900
2	277	125	183	186	4869	651	6617	46182
11	8	10	8	0	24	21	1534	1269
12	10	0	2	0	9	0	56	41
14	0	0	6	0	2	0	70	22
15	0	0	0	0	0	0	28	8
18	2808	957	1400	2313	12461	1590	7660	14357
19	4	3	10	0	30	5	473	2331
22	9	0	27	21	175	2	949	5606
23	0	0	1	0	2	0	202	72
24	6	9	3	0	30	20	593	1051
25	4	2	3	0	34	6	132	458
27	222	177	75	1	3150	318	725	3934
29	2	1	5	0	0	0	151	73
33	0	0	1	0	8	0	88	105
37	0	0	0	0	0	0	79	0
42	2	0	16	0	11	0	18	14
44	0	0	0	0	0	0	5	3
45	0	0	0	0	0	0	0	0
51	0	0	5	0	3	0	32	3
60	127	156	19	10	1376	316	11145	134395
61	11	34	1	4	40	50	420	2272
62	15	84	17	5	86	166	3129	17091
63	3	9	0	2	21	20	193	2909
65	0	0	0	0	5	0	20	175
69	2	5	0	0	22	10	124	2760
70	143	136	21	8	1228	277	10602	121490
72	6	15	8	0	571	7	856	9405
78	11	3	7	3	76	6	252	1135
86	5	2	1	0	9	1	108	606
TOTAL	3675	1728	1819	2553	24242	3466	46261	367767

NOTIONAL FORCES FOR NAVY ASHORE

FLAG	MED CODE	TYPE CODE	TOTAL STRENGTH	MC	NC	MSC	HM	DT
0	1	1087	207	1	0	0	5	4
0	2	1089	148	0	0	0	2	1
0	3	1095	8	0	0	0	1	0
0	4	1102	24	1	0	1	12	0
0	5	1105	0	0	0	0	0	0
0	6	1214	107	0	0	1	0	0
0	7	1226	137	0	0	0	0	0
0	8	1305	290	4	0	6	15	2
0	9	1312	302	1	0	0	8	3
0	10	1327	90	0	0	2	1	0
0	11	1433	114	0	0	0	5	0
0	12	1437	6	0	0	0	1	0
0	13	1438	11	0	0	0	1	0
0	14	1440	24	0	0	1	1	0
0	15	1443	0	0	0	0	0	0
0	16	1452	313	0	0	0	4	4
0	17	1467	782	0	0	0	3	1
0	18	1468	409	0	0	0	0	7
0	19	1471	122	0	0	1	0	0
0	20	1472	749	1	0	1	2	0
0	21	1477	86	1	0	0	0	0
0	22	1514	27	1	0	0	5	0
0	23	1536	179	0	0	0	1	0
0	24	1540	177	0	0	0	2	0
0	25	1557	0	0	0	0	0	0
0	26	1600	49	1	0	0	0	0
0	27	1610	26	1	0	0	0	0
0	28	1612	68	1	1	0	0	0
0	29	1620	0	0	0	0	0	0
0	30	1628	51	3	0	2	4	0
0	31	1629	0	0	0	0	0	0
0	32	1642	0	0	0	0	0	0
0	33	1655	4	0	0	1	3	0
0	34	1661	15	0	0	0	5	0
0	35	1860	81	0	0	0	1	0
0	36	1878	121	0	0	0	1	0
0	37	1880	19	0	0	0	1	0
0	38	1992	130	29	5	60	26	1
0	39	2041	0	0	0	0	0	0
0	40	2043	160	0	0	0	2	0
0	41	2045	583	1	0	0	8	2
0	42	2133	474	0	0	3	3	0
0	43	2135	62	2	2	2	15	0
0	44	2320	88	1	0	0	3	0
0	45	2321	237	1	0	1	2	1
0	46	2333	0	0	0	0	0	0
0	47	2350	54	0	0	0	0	0
0	48	2354	35	0	0	0	0	0
0	49	2373	22	0	0	1	0	0
0	50	2375	309	0	0	0	0	7